

COST AND PERFORMANCE REPORT

Pump and Treat, *in situ* Bioremediation,
and *in situ* Air Sparging of
Contaminated Groundwater at
Site A
Long Island, New York

September 1998



Prepared by:

U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office

SITE INFORMATION

Identifying Information:

Site A, Recycling Facility
Long Island, New York
(Site name is confidential)

CERCLIS #: Confidential

ROD Date: June 24, 1991

Treatment Application:

Type of Action: Remedial

Period of operation: 07/95 - Ongoing
(Mass removal data collected through October 1996)
(Monitoring data collected through October 1997)

Quantity of material treated during application: 10,130,200 gallons through October 1997

Background

Historical Activity that Generated Contamination at the Site: Petroleum bulk storage, chemical bulk storage, chemical mixing, and chemical waste storage

Corresponding SIC Codes: 4226 (petroleum and chemical bulk stations) and 5169 (chemicals and allied products)

Waste Management Practice That Contributed to Contamination: Leaking drums and spills of petroleum and solvent materials

Location: Long Island, NY

Facility Operations: [1,5,7]

- Site A operated as a petroleum bulking facility from 1939 until 1980, and it operated as a petroleum bulking and chemical mixing facility from 1980 to 1984. In 1984, operations ceased when the tenant was evicted by the landlord. The site is adjacent to a harbor.
- In 1984, in response to a toluene spill, the EPA and the New York State Department of Environmental Conservation (NYSDEC) investigated the site. They discovered organics and metals in the soil and organics contamination in the groundwater, surface water, and air. An unknown volume of petroleum products, solvents, and other hazardous waste was released to the soil, groundwater, and surface water via spills and leaks.

- The current site owner was required to remove 255 of 410 on-site drums containing hazardous waste. In 1986, the state removed an additional 700,000 gallons of hazardous waste-containing sludges and drums, including sludge containing polychlorinated biphenyl (PCB) from a tank.
- In June 1986, the site was placed on the National Priorities List (NPL).
- Remedial investigations were performed from 1987 until 1992. Visibly contaminated soils and drums were removed. The investigation found benzene, toluene, ethylbenzene, and xylenes (BTEX). Other contaminants were detected but at concentrations below action levels. The remaining BTEX contamination in the soil and groundwater was left to be addressed through full-scale remediation. Community meetings were held during this time to hear public concern.
- During remedial construction activities in 1995, underground storage tanks were discovered. The tanks contained more sources of BTEX. The tanks were removed, and the contaminant plume was redefined to include this additional area.

Regulatory Context:

- On June 24, 1991, the Record of Decision (ROD) for the site was signed.



SITE INFORMATION (CONT.)

Background (Cont.)

- In 1992, a Consent Decree was entered into which named potentially responsible parties (PRPs). The decree established that remedial operations would be funded by the PRPs for the first six years of operation or until \$1.75 million over and above the sums in a PRP trustfund had been spent, at which point the NYSDEC would assume the costs.
- Site activities are conducted under provisions of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), §121, and the National Contingency Plan (NCP), 40 CFR 300.

Remedy Selection: Extraction and treatment of the groundwater, reinjection of nutrient-enriched, treated groundwater to promote *in situ* bioremediation, *in situ* air sparging, and thermal oxidation of effluent vapors was selected for groundwater remediation based on treatability study results. Soil vapor extraction was selected as the soil remediation remedy, to be used in conjunction with the groundwater remediation system.

Site Logistics/Contacts

Site Lead: State

Oversight: EPA

Remedial Project Manager:

Maria Jon
U.S. EPA Region 2
290 Broadway
New York, NY 10007-1866
(212) 637-3967

State Contact:

Carl Hoffman*
New York State Department of
Environmental Conservation
Bureau of Hazardous Site Control
50 Wolf Road
Albany, New York 13323-7010

*Indicates primary contacts

Treatment System Vendor:

RETEC Associates

Site Management:

Land Tech Remedial, Inc. (1997-Present)
RETEC Associates, Inc. (1993-1997)

Site Contact:

Stephen Hoelscher*
Phillips Petroleum
13 DI Phillips Bldg
Bartlesville, OK 74004
(918) 661-3769

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Groundwater and Vadose Zone Vapors



MATRIX DESCRIPTION (CONT.)

Contaminant Characterization [1,4,5,6]

Primary Contaminant Groups: Volatile organic contaminants

- The groundwater contaminants of concern at the site are benzene, toluene, ethylbenzene, and xylene (BTEX). Other chlorinated volatile organic compounds (CVOCs) and semi-volatile organic compounds (SVOCs) were detected in the groundwater, but at concentrations below action levels.
- The maximum initial concentrations detected in the groundwater were benzene (0.43 mg/L), toluene (350 mg/L), ethylbenzene (5.6 mg/L), and xylene (45 mg/L).
- RETEC, the former site engineers, confirmed the presence of a light nonaqueous phase liquid (LNAPL) when BTEX product was observed in wells on site.
- Figure 1 illustrates the site layout and distribution of contaminant concentrations detected during a 1993 sampling event. A plume map was not available for this site.
- As illustrated in Figure 1, the most elevated BTEX groundwater contamination was primarily detected in the central and western portions of the site. The maximum total BTEX concentration was 299 mg/L detected in 1993 along the western portion of the site. The maximum total BTEX concentration detected in the central portion of the site was 12 mg/L.

Matrix Characteristics Affecting Treatment Costs or Performance [1,5,6]

Hydrogeology:

Three hydrogeologic units have been identified beneath this site.

Level A	Level A is composed of sandy soil and varies in thickness from two feet to 28 feet. It is hydraulically connected to the underlying level, Level B.
Level B	Level B is composed of sand and gravel, with lenses of silt and clay. It varies from 0 to 33 feet of thickness and is hydraulically connected to the underlying level, Level C.
Level C	Level C is composed of sand and varies in thickness from 22 to 55 feet.

The groundwater at the site flows generally to the west, discharging to the harbor. The groundwater flow is tidally influenced in the upper few feet of Level A. Underneath the three units is a clay layer at least five feet in thickness; it is not known if this layer is continuous throughout the site.

At this time contamination has been detected only in the upper 10 feet of groundwater, in Level A. Site engineers have concluded that BTEX contamination has been hydraulically contained in the upper 10 feet of aquifer.

The topography at the site is varied. The elevation of the southwest portion of the site is approximately five feet above mean sea level. The northeast portion of the site, the upper site area, is a hill which reaches a peak elevation of approximately ten feet above mean sea level. A 15-foot berm encloses the top of the hill. Rainfall recharge to the bermed area was determined to cause local mounding of the water table. The water table in the hill area is encountered at depths of 15 to 18 feet below ground surface. In the southwestern portion of the site, the lower site area, the water table is encountered at depths of approximately 8 to 10 feet below ground surface. The water table level in the lower area of the site is tidally influenced. Water levels in the lower site area have risen and flooded soil vapor extraction wells.



MATRIX DESCRIPTION (CONT.)

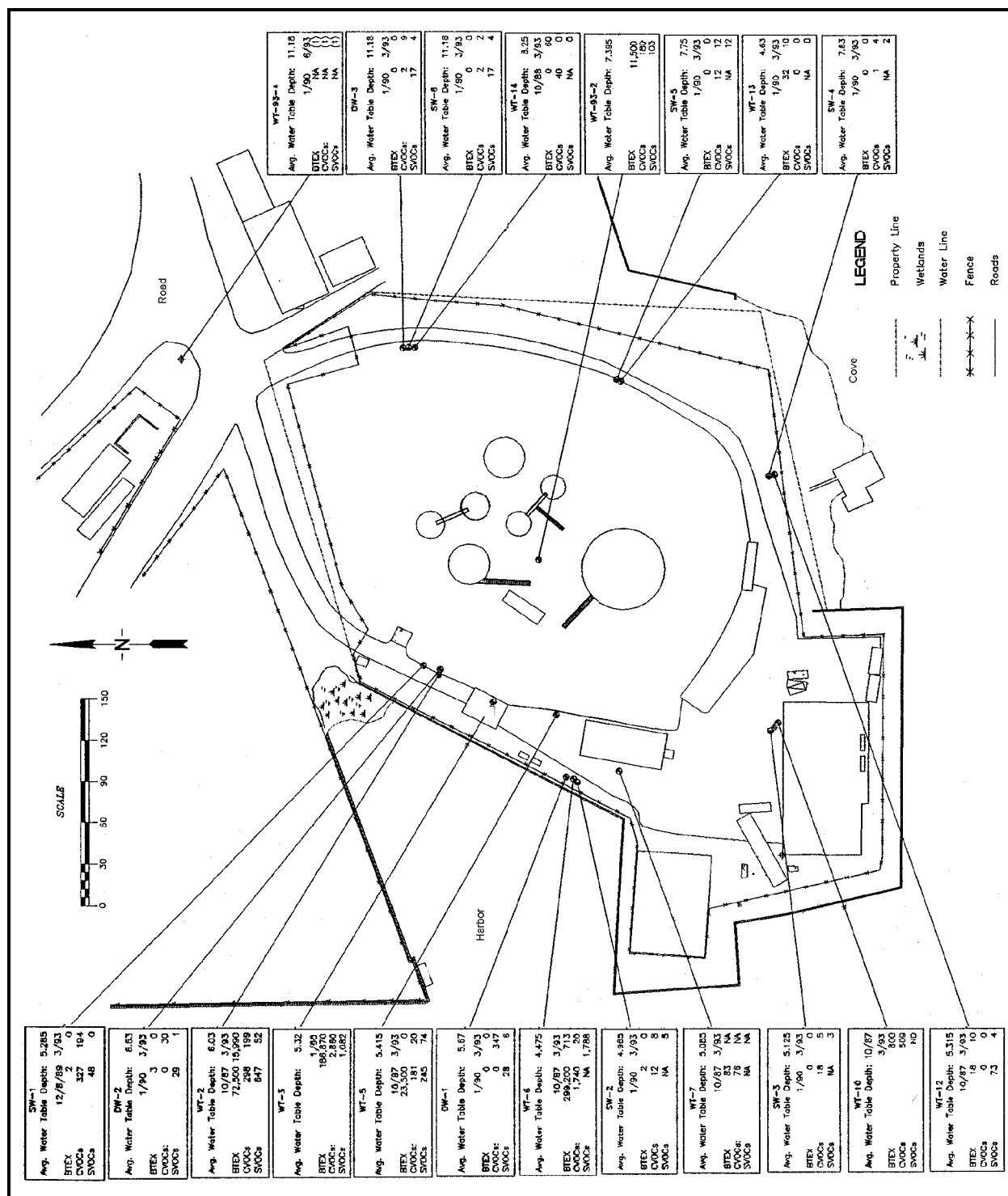


Figure 1. Site Layout and Contaminant Concentrations in the Groundwater, $\mu\text{g/L}$
(1993, Best Copy Available) [5]

MATRIX DESCRIPTION (CONT.)

Matrix Characteristics Affecting Treatment Costs or Performance (Cont.)

Tables 1 and 2 present technical aquifer information and well data, respectively.

Table 1. Technical Aquifer Information

Unit Name	Thickness (ft)	Conductivity (ft/day)	Average Velocity (ft/day)	Horizontal Flow Direction
Level A	2-28	53.5	1.80	West ^a
Level B	0-33	53.5	1.80	West
Level C	22-55	53.5	1.80	West

^a Groundwater flow is tidally influenced in Level A but generally flows to the west and discharges into the harbor.

Source: [5,6]

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Pump and treat (P&T) with air stripping, *in situ* bioremediation, *in situ* air sparging, and soil vapor extraction (SVE).

Supplemental Treatment Technology

Nutrient addition and pH adjustment of liquid-phase effluent prior to reinjection and thermal oxidation of all system effluent vapor streams.

System Description and Operation [2,3,6,8]

Table 2. Extraction Well Data

Well Name	Unit Name	Screen Depth Below Water Table (ft)	Design Yield (gal/min)
GWX-0	Level A	10	1-3
GWX-1	Level A	10	1-3
GWX-2	Level A	10	6-8
GWX-3	Level A	10	1-3
GWX-4	Level A	10	1-3

Source: [5,6]

System Description

- The groundwater extraction system consists of five wells installed in the plume, all screened at depths of approximately ten feet below the water table. Table 2 presents extraction well data. Wells were placed in the areas of highest contamination. Groundwater is continuously withdrawn from the shallow aquifer, Level A, and treated through an air stripper. From 1995 to 1996, RETEC calculated that the system operated at an overall average extraction rate of 18 gpm, based on the actual volume of water treated.
- Well GWX-2 was placed in an area where free-phase BTEX product was observed in the western portion of the site. The extraction rate from GWX-2 was designed to be 6-8 gpm, greater than the 1-3 gpm design extraction rate for the other four wells. The elevated extraction rate in well GWX-2 promoted recovery of free-phase BTEX as well as recovery of the more highly contaminated part of the plume.



TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

- The treatment system consists of a feed holding tank, a low profile air stripper, gravity separation tanks, effluent storage tanks, and a sand filter.
- The feed holding tank regulates groundwater flow to the air stripper from the extraction wells. The extracted water is fed to the air stripper at a constant rate of 18 gpm through a pipe located at the bottom of the tank.
- The air stripper is a stacked, stainless steel tray tower, consisting of four trays stacked 77 inches high. Each tray is 44 inches wide and 32 inches deep. Countercurrent flows of air and water are sent through the air stripper.
- Effluent from the air stripper passes through gravity separation/effluent storage tanks. Metals (at levels below concern) and particulate matter are gravity separated and filtered into a sludge. The sludge is pumped out for eventual off-site disposal. The remaining water is then treated for reinjection.
- The water is treated to promote *in situ* bioremediation when reinjected. The pH of the water is adjusted in the effluent storage tank. Treated water is then pumped through a sand filter, and nutrients are added to adjust the nitrogen and phosphorous levels.
- The treated water is reinjected into the aquifer through a reinjection trench located upgradient of the plume.
- Enhanced *in situ* bioremediation is achieved by adding nutrients at the reinjection point and supplying oxygen through air sparging points. BTEX compounds are biodegraded to end products of carbon dioxide and water by heterotrophic organisms (refer to later discussion under Performance Data Assessment, regarding heterotrophs)
- Pilot tests determined that optimal conditions for BTEX degrading organisms include a pH between 6.0 and 8.0 and nitrogen and phosphorus levels between 1 and 5 mg/L each. Target dissolved oxygen levels are between 2 and 8 mg/L.
- The SVE and air sparging systems are composed of air sparging and SVE wells. Air is injected through 44 sparging wells at points approximately 10 feet below the water table. The sparging system is pulsed at a system interval time of one day on two days off and at a period time of two hours on and one hour off.
- The effluent vapors from the sparging points are collected by 20 SVE wells. The SVE wells, 14 vertical and six horizontal, were placed in the vadose zone, a few feet above the water table. In the upper site area, the 16 vertical vapor extraction wells were placed at an average a depth of 12 feet. In the lower site area, the six horizontal vapor extraction wells were placed approximately six to eight feet deep. Horizontal wells were used in the lower site area because the groundwater is shallow.
- The SVE wells in the lower site area occasionally become flooded because groundwater levels are tidally influenced. These SVE wells are equipped with water level detectors which automatically shut off the wells to protect the system from taking in water. When water levels rise, only the affected wells are shutdown while the remainder of the SVE system continues to operate.
- The lower area of the site is paved to seal out atmospheric vapors from the SVE system and to further extend the radius of influence of the horizontal vapor extraction lines.
- The effluent vapors from the SVE system and from the air stripping tower pass through a thermal oxidation unit to destroy the VOCs before discharge to the atmosphere.
- Groundwater quality is monitored quarterly through a combination of five extraction wells, two air sparging wells, and three shallow monitoring wells. The air sparging/SVE system performance is

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

monitored quarterly by analyzing soil vapor in 20 vapor extraction wells and five vapor monitoring points. The vapor-phase loading to the thermal oxidation unit and the effluent to the thermal oxidation unit is monitored on a monthly basis.

System Operation

- Quantity of groundwater pumped from the aquifer in gallons:

Year	Volume Pumped (gal)
July 1995 - July 1996	1,550,000
August 1996 - July 1997	6,730,000
August 1997 - October 1997	305,000

- Since September 1995, the P&T system has operated approximately 75% of the time. Problems during startup, primarily iron clogging in the injection wells, caused the low operation rate. Iron levels decreased after the first month of operation, and well clogging is no longer a problem. Currently, the treatment system is shut down on a weekly basis to clean the extraction wells and backflush the sand filter.
- The *in situ* air sparging and SVE system has been operational approximately 90% of the time.

- Nutrients, in the form of ammonium chloride, monopotassium phosphate, and dipotassium phosphate, are dissolved in batches and added to the effluent tank approximately every two weeks.
- The original air sparging and SVE system was expanded in September 1995 to address the underground storage tank contamination detected during demolition activities. Five air sparging wells and two SVE wells were added in the lower site area; two additional air sparging wells were added in July 1996. The air sparging and SVE system described under System Description reflects this expansion.
- LNAPL was visually observed in the air stripper influent holding tank in 1995 and 1996. Groundwater to be treated is fed from the bottom of the tank to avoid treating the LNAPL through the stripper. The free product was vacuumed into a wastewater truck for off-site disposal. The amount of free product recovered was not monitored, but the RETEC site contact estimated that approximately 40 gallons of free product were recovered in 1995 and 1996. No product was observed in 1997.

Parameters Affecting Treatment Cost or Performance

The major operating parameters affecting cost or performance for the technologies used at this site are listed in Table 3.



TREATMENT SYSTEM DESCRIPTION (CONT.)

Parameters Affecting Treatment Cost or Performance (Cont.)

Table 3: Performance Parameters

Parameter	Value
Average P&T Extraction Rate	18 gpm (design)
Soil Vapor Extraction Vacuum Rate	660 scfm (design)
System Sparge Rate	330 scfm (design)
Performance Standards for <i>In Situ</i> Bioremediation	6.0 < pH < 8.0 1 mg/L < Nitrogen < 5 mg/L 1 mg/L < Phosphorus < 5 mg/L 2 mg/L < Dissolved Oxygen < 8 mg/L
Performance Standards for P&T Reinjection (Primary Drinking Water Standards)	benzene 0.0007 mg/L toluene 0.005 mg/L ethylbenzene 0.005 mg/L xylene 0.005 mg/L
Remedial Goals (aquifer)	NYSDEC Primary Drinking Water Standards (see above)

Source: [2, 3]

Timeline

Table 4 presents a timeline for this remedial project.

Table 4: Project Timeline

Start Date	End Date	Activity
6/10/86	---	Site listed on NPL
1987	1991	Remedial Investigation and Feasibility Study performed
06/91	---	Record of Decision signed
06/92	---	Consent Judgment entered into
09/92	---	Pre-Remedial & Remedial Design Activities begin
03/94	---	Remedial Design Approved by New York State Department of Environmental Conservation
05/94	---	Site structures decommissioned and demolished
08/94	07/95	Remedial system constructed
---	07/95	System begins operation and quarterly monitoring begins
09/95	---	Extraction system is expanded
7/96	---	Additional air sparging wells added

Source: [1, 2]



TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards

The groundwater cleanup goal for this site is to remediate the groundwater to meet the Maximum Contaminant Levels (MCL) established by the NYSDEC, which are the Primary Drinking Water Standards. The cleanup goals are listed in Table 3 and are applied throughout the aquifer, as measured in all on-site monitoring wells [1].

Treatment Performance Goals [1,2]

- The primary performance goal of the extraction system is to contain the contaminant plume and prevent it from discharging to the harbor. The goal is both horizontal and vertical containment.
- The primary performance goal of the treatment system is to reduce BTEX concentrations to the performance standards listed in Table 3.
- The primary performance goal regarding *in situ* bioremediation is to maintain a pH level between 6.0 and 8.0, nitrogen and phosphorous levels between 1 and 5 mg/L, and dissolved oxygen levels between 2 and 8 mg/L.
- The primary performance goals of the air sparging system are to sparge at the minimum rate needed to achieve BTEX removal and to maintain a dissolved oxygen level between 2 and 8 mg/L to promote *in situ* bioremediation.

Performance Data Assessment [3,4,6,8]

Total BTEX includes benzene, toluene, ethylbenzene, and total xylenes.

- Maximum BTEX levels have declined from 153 mg/L to 27 mg/L, a reduction of 82 percent. However, cleanup goals have not been met at this site [3]. Monitoring data in 1997 indicate elevated BTEX levels persist in wells along the western portion of the site.
- Figure 2 illustrates that, overall, average BTEX levels have been reduced from 0.160 to 0.026 mg/L. Average concentrations of individual constituents were reduced to 0.0008 mg/L (benzene), 0.002 mg/L (toluene), 0.001 mg/L (ethylbenzene), and 0.01 mg/L (xylene). However, the October 1997 sampling event revealed maximum benzene levels of 0.008 mg/L, maximum toluene levels of 14.0 mg/L, maximum ethylbenzene levels of 0.018 mg/L, and maximum xylenes levels of 13.4 mg/L, all above cleanup goals.
- Containment of the plume appears to have been achieved based on quarterly groundwater monitoring results.
- For the enhanced *in situ* bioremediation, performance standards for nitrogen were met from July 1995 to July 1997. During that time, average monthly nitrogen levels were between 2 and 5 mg/L. However, from July 1996 to October 1996, nitrogen levels were above the 5 mg/L performance standard.
- For the enhanced *in situ* bioremediation, performance standards for phosphorous were met from June to October 1997. During this time, average phosphorus levels were at 1 mg/L. However, from July 1995 through May 1996, average phosphorus levels were below the 1 mg/L performance standard.



TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Assessment (Cont.)

- For the enhanced *in situ* bioremediation, performance standards for dissolved oxygen were met from July 1995 through March 1996 and from August 1996 through October 1997. During this time, average dissolved oxygen levels were between 2.0 and 8.0 mg/L. However, from April 1996 through July 1996, dissolved oxygen levels were below the 2.0 mg/L performance standard.
- Between July 1995 and July 1996, approximately 8,845,200 gallons of groundwater passed through the air stripper. Based on computer model results which accounted for location of air sparging points and groundwater flow, RETEC approximated that the air-sparging/SVE system treats approximately 686,000 gallons per year. Based on those values, the total volume of groundwater treated through both the P&T and air sparging systems between July 1995 to October 1996 was 9,703,500 gallons.
- Figure 3 presents the removal of BTEX by the P&T and air sparging treatment systems from July 1995 to October 1996. From July 1995 to July 1996, the P&T system and the air sparging system have removed approximately 5,314 pounds of BTEX from the groundwater. The contaminant mass removed by the SVE system is not included in this estimate because this report addresses the groundwater remedy, not the soil remedy.
- In addition to the contaminant removal illustrated in Figure 3, the *in situ* bioremediation is believed to provide continuous treatment of a portion of the plume. The mass of contamination degraded through bioremediation is not measured directly. However, the site operators measure the number of heterotrophs in the groundwater. Monitoring data has shown that the population of heterotrophs has been sustained.
- The mass of free product recovered by the extraction system is not included in Figure 3.
- According to measurements performed by RETEC (see next section), the air sparging system removed approximately 85% of the 5,314 pounds of BTEX. The P&T system removed 15% of the BTEX.
- The BTEX removal rate reached a peak of approximately 20.1 lbs/day after six months of operation. The cumulative removal rate has varied between 20.1 lb/day and 7.6 lb/day during the life of the system.
- LNAPL has not been observed in any wells since the April 1996 sampling event. The small BTEX plume in the area of well GWX-2 is believed to have been recovered. However, GWX-2 will continue to be pumped at a higher rate compared to the other wells to extract the more concentrated portion of the plume.
- Effluent BTEX levels are not measured prior to reinjection.

Performance Data Completeness [3,4]

- Data are available for BTEX concentrations in the groundwater in some wells during quarterly sampling events from July 1995 to October 1997. Data were obtained for the October 1996 quarterly sampling event but were not included in the analysis, as explained below in Performance Data Quality. The air stripper influent and effluent have not been monitored for contaminant levels. Data on vapor from sparging and SVE are available in some SVE wells during quarterly sampling events from July 1995 to October 1996. Vapor contaminant loading to the thermal destruction unit has been measured on a monthly basis. Quarterly monitoring data are available in Quarterly Monitoring Reports. Weekly monitoring data are summarized in the monthly reports, and actual weekly readings are available from the site engineer.



TREATMENT SYSTEM PERFORMANCE (CONT.)

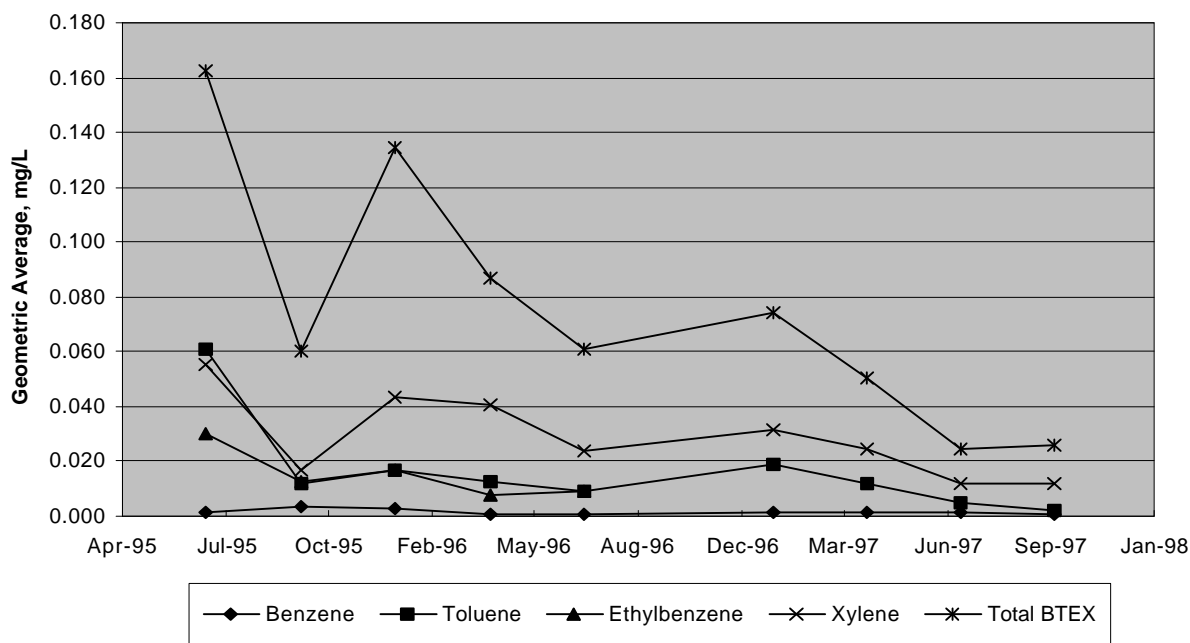


Figure 2. Average BTEX Concentrations (from July 1995 to July 1996)* [3,6]

*Data from October 1996 were not included - see Performance Data Quality

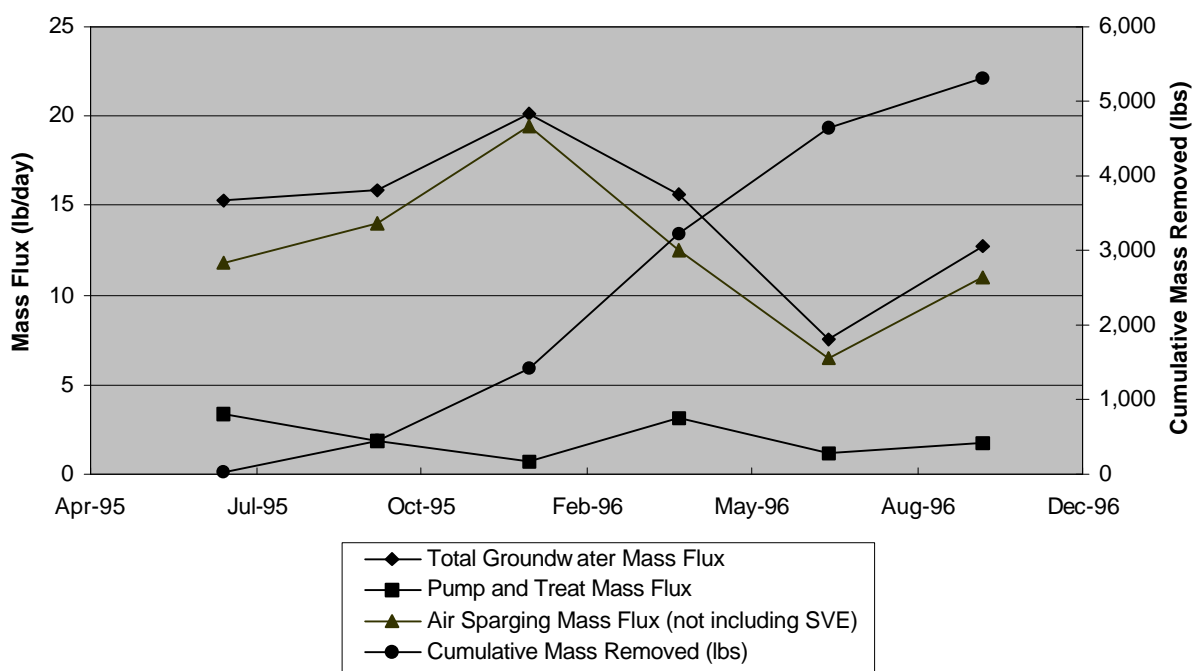


Figure 3. Mass Flux Rate and Cumulative Contaminant Removal (July 1995 to October 1996) [3]

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Completeness (Cont.)

- Total BTEX mass removal was determined by RETEC using analytical results from influent to and effluent from the thermal destruction unit. RETEC calculated the BTEX mass removed by the SVE system and the air sparging system based on charcoal tube data sampled on a quarterly basis. RETEC determined the mass removed by the P&T system as the difference between the total BTEX removal and the BTEX removal by the SVE system and the air sparging system. RETEC calculated that the mass removed by the air sparging system alone was based on an observed 7:3 ratio between mass removed by SVE to mass removed by air sparging.
- The BTEX mass removed by the P&T system did not include the free product mass that is separated prior to treatment. The amount of free product recovered was not monitored.
- A geometric mean was used for average groundwater concentrations detected in five extraction wells, two air sparging wells, and three shallow monitoring wells located within the original plume area. A geometric mean was used to show the trend across the entire plume. When concentrations below detection limits were encountered, half of the detection limit was used.

Performance Data Quality

- The sampling event performed in October 1996 did not meet QA/QC requirements in that BTEX concentrations were detected in both trip and field blanks. Therefore, data from this sampling event were not included in the analyses performed in this report [3].
- The QA/QC program used throughout the remedial action met the EPA and the State of New York requirements. All monitoring was performed using EPA-approved SW-846 Methods 601, 602, 624, 625, 353.2, 365.2. The only vendor-noted exception to the QA/QC protocols occurred during the October 1996 sampling event described above [3].

TREATMENT SYSTEM COST

Procurement Process

The group of responsible parties contracted with RETEC to design and construct the remediation system, under the oversight of the NYSDEC. After six years of system operation or after \$1.75 million over and above the sums in a trust fund have been spent, the NYSDEC will take over system operation and will assume the remaining costs.

Cost Analysis

The responsible parties assumed all costs for design and construction and operation of the treatment system at this site.



TREATMENT SYSTEM COST (CONT.)

Capital Costs [6.7]

<u>Remedial Construction</u>	
Well construction (extraction, monitoring, sparge, SVE)	\$1,007,915
Treatment system (air stripper, holding, tanks, chemical mixing tanks)	\$97,944
Building	\$100,960
Fence/Security	\$17,392
Construction Management	\$122,579
Total Remedial Construction	\$1,583,133

Operating Costs [6.7]

Utilities	\$59,782
Operations & Maintenance	\$90,903
Monitoring	\$30,658
Consumable (Chemicals and Nutrients)	\$27,291
Disposals (sludge, free product)	\$9,663
Project Management and Reporting	\$121,209
Miscellaneous	\$18,921
Total Operating Cost (July 1995 - October 1996)	\$358,427

Other Costs [6.7]

<u>Remedial Design</u>	
Remedy	\$539,320
Expansion	\$32,586
Excavation and disposal of tanks	\$179,035
Demolition of buildings	\$57,308
EPA and NYSDEC Oversight	\$20,000

Cost Data Quality

Actual capital and operations and maintenance cost data are available from the responsible party contact and the treatment vendor for this application. The cost of SVE wells (source control) could not be separated from the groundwater system costs.

OBSERVATIONS AND LESSONS LEARNED

- Actual costs for the P&T, *in situ* bioremediation, and *in situ* air sparging and soil vapor extraction treatment application at Site A were approximately \$1,941,560 (\$1,583,133 in capital and \$358,427 in operations and maintenance), which corresponds to \$365 per pound of contaminants removed and \$200 per 1,000 gallons of groundwater treated.
- The site remediation system has been in operation for two years and three months. No substantial changes to the cost of the remedial system at this site were incurred during implementation. The system expansion constructed in September 1995 is included in the presented costs and had no impact on schedule [7].
- According to the site contact, the use of skid-mounted modular equipment reduced construction costs. Additionally, the responsible parties have indicated the competitive bidding process used resulted in lower costs [7].
- The groundwater cleanup goals for this site have not been met after two years and three months of operation. However, the selected remedy has worked to contain the plume, reduce average BTEX concentrations, and to recover LNAPL.
- RETEC observed the air sparging portion of the system has accounted for 85% of BTEX removal from the groundwater, while the P&T system accounted for 15% of BTEX removal in the groundwater.



OBSERVATIONS AND LESSONS LEARNED (CONT.)

- The success of the remedial systems is, in part, due to the simple aquifer material under the site. The uniform sandy soil at the site allowed sufficient sparging and SVE rates, as well as simplified zones of influence for extraction wells.
- The heterotroph population has been maintained at the level necessary to achieve bioremediation [8].
- Nitrogen levels met the performance goals of 1 to 5 mg/L from July 1995 through June 1996 but were above 5 mg/L from July 1996 to October 1997. The site operator encountered levels above 5 mg/L in 1997, and the amount of ammonium chloride added was reduced [3].
- Phosphorous levels did not meet performance goals and were detected below the optimal range of 1 to 5 mg/L from June 1996 to October 1996. In 1997, the phosphorous levels increased to optimal levels.
- The performance of the treatment system and the area of influence of the enhanced *in situ* bioremediation system could not be determined because it is not monitored.

REFERENCES

1. Record of Decision, U.S. Environmental Protection Agency, Site B. June 24 1991.
2. Remedial Action Report, RETEC. February 1996.
3. In situ Monitoring for the Integrated Subsurface Remediation System, RETEC. February 1997.
4. Monthly Operations Report, RETEC. December 1996.
5. Preremedial Design Investigation Report, RETEC. July 1993.
6. Correspondence with Mr. Steve McNerny, RETEC, April 1997 and May 1997.
7. Correspondence with Mr. Steve Hoelsher, Phillips Petroleum, September 23, 1997.
8. Correspondence with Mr. Chris Poole, Land Tech, June and July 1998.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Eastern Research Group, Inc. and Tetra Tech EM Inc. under EPA Contract No. 68-W4-0004.



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